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Trenching and Excavation: Safety Principles[1]

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Trenching and excavation procedures are performed thousands of times a day across the United States. Unfortunately, more than 3,000 people were killed in trenching accidents in 1989 alone. Contractors and construction laborers should understand the laws and regulations applicable to trenching and excavation occupations. These statutes are in effect for the express purpose of protecting those who work in trenching and excavation situations. Although farmers are generally exempt from the state trenching and excavation statutes, they may still be held liable for accidents and loss of life resulting from trenching and excavation activities conducted under their direction.

This publication provides Ohio's construction contractors, laborers and farmers with an overview of soil mechanics relating to trench and excavation failures, and of Ohio's trenching and excavation laws. It is not intended to provide the reader a strict legal interpretation, but to increase his/her awareness of excavation and trench safety, and provide guidance on where to obtain more information.

SOIL MECHANICS

In trenching and excavation practices, "soil" is defined as any material removed from the ground to form a hole, trench or cavity for the purpose of working below the earth's surface. This material is most often weathered rock and humus known as clays, silts and loams, but also can be gravel, sand and rock. It is necessary to know the characteristics of the soil at the particular job site. Soils information is used by contractors and engineers who are trained to identify the proper safety protective devices or procedures needed for each situation. (The U.S. Department of Labor's Office of Occupational Safety and Health Administration, OSHA, stresses the need for a "competent person" to be in charge of all excavation and trenching activities at a job site.) Soil scientists and geotechnical specialists can be helpful in identifying and characterizing soil materials. Contact your county Soil Conservation Service office for a list of soil scientists in your area, and/or consult the telephone Yellow Pages under the heading of "engineers" with the specialty of "geotechnical" and/or "soils."

Soil is an extremely heavy material, and may weigh more than 100 pounds per cubic foot (pcf). A cubic yard of soil (3 ft x 3 ft x 3 ft), which contains 27 cubic feet of material, may weigh more than 2,700 pounds (lbs). That is nearly one and a half tons (the equivalent weight of a car) in a space less than the size of the average office desk. Furthermore, wet soil, rocky soil or rock is usually heavier. The human body cannot support such heavy loads without being injured.

From a soil mechanics point of view, one can visualize the soil as a series of multiple columns of soil blocks, with the blocks piled one on top of the other. In the soil column shown in Figure 1, each soil block measures one foot square, weighs approximately 100 lbs,

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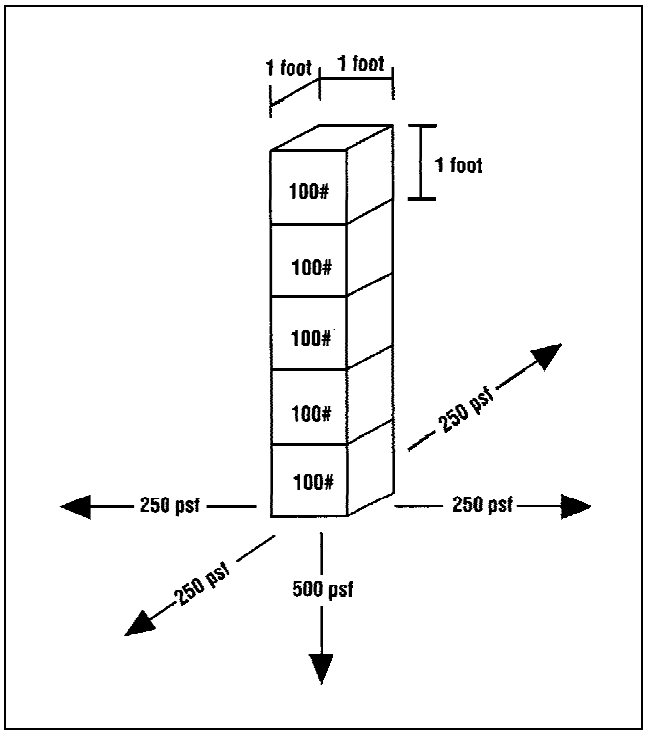

Figure 1. Forces exerted by a column of soil (abstracted from Mickle, 1991).

and supports the weight of all of the blocks above. This means that a block sitting at a five-foot depth supports its own weight and the combined weight of the four blocks resting on it. The combined weight of this column is 500 lbs spread over a one-square-foot area; 500 pounds per square foot (psf). This five block column constitutes a 500 pound force exerted vertically on whatever lies below.

A column of soil exerts not only a vertical force, but also a horizontal force in all outward directions. The outward force is equal to one-half the vertical force. For example, the five-block column illustrated in Figure 1 has a downward vertical force of 500 lbs at the base of soil block number five. The horizontal force pushing out from the base of that same block is half of 500 lbs, or 250 lbs, in all outward directions. As the weight of the column increases, the soil blocks at the bottom of the column theoretically have a tendency to compress and spread outward. In undisturbed soil conditions, this process is stopped by the presence of the surrounding columns pushing back with equal pressure. These hypothetical columns press against each other, maintaining an equilibrium. Therefore, the horizontal pressures of all the columns are balanced, producing a stable relationship.

TRENCH FAILURE

When a trench is excavated, the stable relationship described in the previous section no longer exists (see Figure 2). The horizontal pressure on the soil blocks along the trench wall is no longer in equilibrium, and a block may not be able to support its weight and the weight of any blocks above. At the point where the soil can no longer withstand the pressure, the wall will shear and break away from its stable position, as indicated in Figure 2a. The first failure occurs as the bottom of the wall moves into the trench (see Figure 2b). This movement creates an undercut area at the base of the trench as soil material along the wall falls into the trench. Often there is a second movement in which more of the wall material erodes. Finally, the erosion at the base of the trench leaves the upper part of the column supported only by cohesion to the columns around it (see Figure 2c), and more soil from the column will soon fall into the excavation (see Figure 2d). Many rescue attempts are unsuccessful because rescuers attempt to save victims before the second and third failures take place, often trapping the would-be rescuers along with the first victims.

Figure 2e summarizes the three areas of failure in the trench wall as explained in the example above. In order of occurrence, soil in Area 1 at the base of the wall moves into the trench, and then is followed by the failure of Area 2. The failure of Areas 1 and 2 leave the remaining trench wall, Area 3, unsupported. Area 3 will break the cohesion and shear off the wall under its own weight and fall into the trench. Typically, time elapses between the failure of segments. It is the uncertainty of when the next failure will occur that makes rescue or recovery extremely hazardous. Time is a major consideration. The longer the trench is unsupported, the more potential there is for further trench collapse.

Some employers and contractors believe that proper safety procedures waste valuable time and money, and that faster work creates larger profit margins. However, accidents that occur because safety precautions are not taken can be costly. In addition to the loss of human life, the possible financial costs of a trenching accident include: work stoppage to rescue the victim; additional time and labor to re-excavate the collapsed trench; workers compensation costs and increased insurance premiums; and additional paperwork resulting from the investigation of the accident. In some cases, fines are also imposed. For example, OSHA recently fined a contractor $232,000 after the death of a worker in a trench cave-in. Six company employees were in a 12-foot deep trench when it collapsed, killing one person

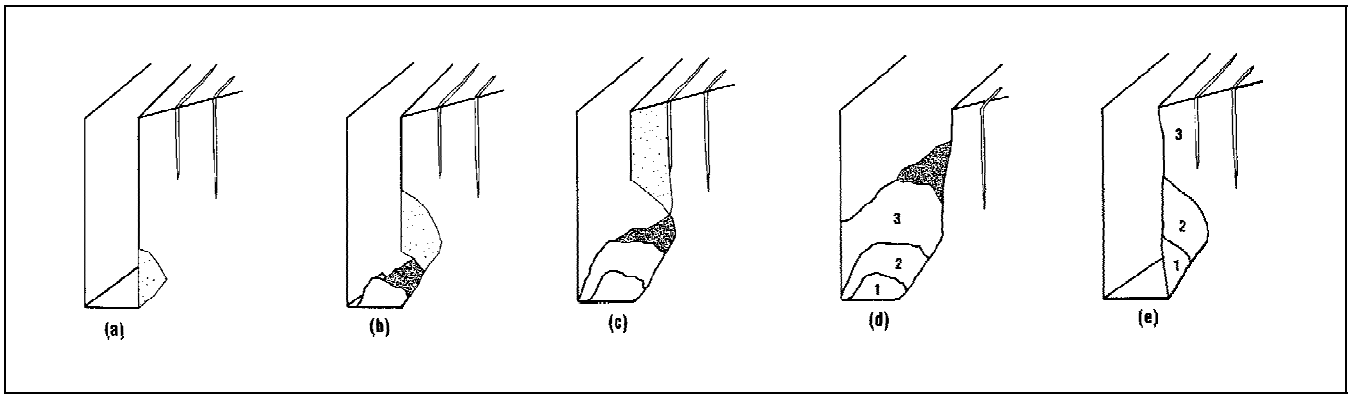

Figure 2. Mechanics of a trench failure (abstracted from Mickle, 1991).

and injuring another. OSHA determined that the trench was not properly supported. In another case, OSHA cited a company $580,000 for the alleged willful and serious violations of federal excavation standards. The combination of potential fines, loss of human life, personal lawsuits and poor public relations could mean the end of a successful business.

GENERAL REQUIREMENTS

When performing trenching and excavation operations in Ohio, there are general precautions that should be considered before starting any work. Contact the Ohio Utility Protection Service, OUPS (1-800-362-2764), and the Oil and Gas Producers Protection Service (614-587-0486), to identify the location of any underground cables, pipes or utility installations in the area of the proposed excavation. Ohio law requires excavators to call OUPS two working days before breaking ground. Once these areas are located and marked, avoid them. When working in areas where there is a back-filled trench, or a railroad, highway, source of vibration or other unstable condition, take additional precautions to properly shore and brace the excavation. These precautions will help prevent cave-ins. Undercutting of exposed vertical faces is prohibited unless supported by one or more of the methods prescribed in the Ohio Administrative Code, Chapter 4121:1-3, for exposed faces of trenches. Place all excavated or fill materials a minimum of two feet away from the top edge of the trench. If materials need to be placed closer than two feet from the edge of the trench, install an effective barrier to prevent them from falling into the excavation.

The following is a summary of the trenching and excavation laws that apply in Ohio. (Consult the Ohio Administrative Code, Chapter 4121:1-3, directly for further details.)

Trenches

Exposed trench faces that are more than five feet high must be stabilized by either shoring, sloping the face of the wall back to a stable slope or some equivalent method to prevent cave-ins. (The definition of stable slope is based on soil properties as noted in the Ohio Administrative Code, Chapter 4121:1-3.) If the trench is excavated in hard, compact soil materials more than five feet in depth, the wall must be supported. If the walls of a trench are less than five feet deep and in soft or unstable soil materials, then trench boxes, shoring, sheeting, bracing, sloping or other equivalent methods are required to prevent the trench wall from collapsing. Trench walls above five feet in height may be sloped instead of shored.

Materials used for trench boxes, sheeting, sheet piling, bracing, shoring and underpinning should be in good condition, and should be installed so that they provide support that is effective to the bottom of the trench. Timber must be sound and free from large or loose knots. Vertical planks in the bracing system should be extended to an elevation no less than one foot above the top of the trench face.

When employees are required to be in trenches that are four feet or more in depth, an adequate means of exit, such as a ladder or steps, must be provided and located so that no more than 25 feet of lateral travel is required for a person to reach the exit structure. The trench should be braced and shored during excavation and before personnel are allowed entry. Cross braces and trench jacks should be secured in true horizontal positions and spaced vertically in order to prevent trench wall material from sliding, falling or otherwise moving into the trench. Portable trench boxes (also called sliding trench shields) or safety cages may be used to protect employees instead of shoring or bracing. When in use,

these devices must be designed, constructed and maintained in a manner that will provide at least as much protection as shoring or bracing, and extended to a height of no less than six inches above the vertical face of the trench.

During the backfill operation, backfill and remove trench supports together, beginning at the bottom of the trench. Release jacks or braces slowly and, in unstable soil materials, use ropes to pull them from above after employees have left the trench.

Excavations

Excavation safety requirements are quite similar to trenching requirements. For excavations in which employees may be exposed to unstable ground, qualified personnel using practices that are compatible with standards required by a registered architect, a registered professional engineer or other duly licensed or recognized authority will design support systems such as piling, cribbing, bracing and shoring that meet accepted engineering requirements to contain the walls. Excavations with conditions such as water, silty materials, loose boulders, erosion, deep frost action or earth fracture planes require that the slope of the earth adjacent to the excavation be lessened. Scaling, benching, barricading, rock bolting, wire meshing or other equally effective means of excavation support must meet accepted engineering requirements for all sides, slopes and faces of excavations. Materials used to support excavations should be maintained in good condition.

Never excavate below the level of the base of the footing or retaining wall, except in hard rock, unless the wall is underpinned and appropriate precautions are taken to ensure the stability of adjacent walls. If it is necessary to place or operate power shovels, derricks, trucks, materials or other heavy objects on a level above and adjacent to an excavation, the side of the excavation must be sheet-piled, shored, braced or sloped as necessary to resist the additional pressure resulting from such loads. Install substantial stop logs or barricades when using mobile equipment on or near an excavation, grade away from the excavation, and provide walkways or bridges with standard guardrails for employees or equipment to cross over excavations.

SUMMARY

This publication provides an overview of the basic soil mechanics of a trench failure, and Ohio and federal laws which regulate trenching and excavation activities. The actual laws applicable in Ohio can be found in Chapter 4121:1-3 of the Ohio Administrative Code, which can be obtained from larger public libraries, private law firms, the office of your county district attorney and OSHA offices. OSHA can provide manuals, drawings, etc., and all federal regulations and requirements. For more information, contact any of the following:

- US Department of Labor — Occupational Safety and Health (OSHA)
  Ohio Office: Federal Building, 200 North High Street, Columbus, OH 43215 (614) 469-5582
  Region V Office: 230 South Dearborn Street, Room 3244, Chicago, IL 60624 (312) 353-2220

- Ohio Workers Compensation, Division of Safety and Hygiene, South-Central Regional Office, 6929 American Parkway, Reynoldsburg, OH 43068 (1-800-852-7464)

- Ohio Land Improvement Contractors' Association (OLICA), Box 116, Dublin, OH 43017

KEY POINTS

- Identify the soil characteristics at the work site, and use this information to provide a safe work place for construction laborers.

- Use prescribed methods of wall retention, piling, cribbing, sloping, shoring, trench boxing and sheeting to maintain trench and excavation walls. For each trenching or excavation situation, you should employ the proper sloping, shoring and bracing structures and measures designed specifically for the particular situation.

- Trench failures often occur in multiples, starting with a movement of soil material near the bottom of the trench wall. After the failure of the base, the support of the wall will quickly erode and the wall will collapse. The collapsing soil is extremely heavy and can weigh one and a half tons per cubic yard, producing a tremendous crushing force.

- Proper design, construction and placement of support structures will allow employees to work in a safe environment.

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